

**TRANSMITTAL LETTER TO THE UNITED STATES
DESIGNATED/ELECTED OFFICE (DO/EO/US)
CONCERNING A FILING UNDER 35 U.S.C. 371**

003300-877

U.S. APPLICATION NO. (If known, see 37 C.F.R. 1.5)

Unassigned **10/018082**INTERNATIONAL APPLICATION NO.
PCT/SE00/01376INTERNATIONAL FILING DATE
29 June 2000

PRIORITY DATE CLAIMED

9 July 1999 and 24 August 1999

TITLE OF INVENTION

MICROSCOPE FILTER FOR AUTOMATIC CONTRAST ENHANCEMENT

APPLICANT(S) FOR DO/EO/US

ANDERS HEYDEN

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include items (5), (6), (9) and (21) indicated below.
4. ☐ The US has been elected by the expiration of 19 months from the priority date (Article 31).
5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
 - a. ☒ is attached hereto (required only if not communicated by the International Bureau).
 - b. ☒ has been communicated by the International Bureau.
 - c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☐ An English language translation of the International Application as filed (35 U.S.C. 371(c)(2))
 - a. ☐ is attached hereto.
 - b. ☐ has been previously submitted under 35 U.S.C. 154(d)(4).
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
 - a. ☐ are attached hereto (required only if not communicated by the International Bureau).
 - b. ☐ have been communicated by the International Bureau.
 - c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
 - d. ☒ have not been made and will not be made.
8. ☐ An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. ☐ An English language translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11 to 20 below concern document(s) or information included:

11. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. ☒ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☒ A **FIRST** preliminary amendment.
14. ☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
15. ☐ A substitute specification.
16. ☐ A change of power of attorney and/or address letter.
17. ☐ A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U.S.C. 1.821 - 1.825.
18. ☐ A second copy of the published international application under 35 U.S.C. 154(d)(4).
19. ☐ A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).
20. ☒ Other items or information: Transmittal of Formal Drawings. Certified copies of Swedish Application No. 9902641-1 filed 9 July 1999 and United States Provisional Application No. 60/150,440 filed 24 August 1999 were submitted during the international phase of prosecution. Thus, the claims for priority have been perfected.



21839

U.S. APPLICATION NO. (If known, see 37 CFR 1.51) not assigned 10/018082	INTERNATIONAL APPLICATION NO. PCT/SE00/01376	ATTORNEY'S DOCKET NUMBER 003300-877
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21. <input checked="" type="checkbox"/> The following fees are submitted: Basic National Fee (37 CFR 1.492(a)(1)-(5)): Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to U.S. PATENT AND TRADEMARK OFFICE and International Search Report not prepared by the EPO or JPO \$1,040.00 (960) International preliminary examination fee (37 CFR 1.482) not paid to U.S. PATENT AND TRADEMARK OFFICE but International Search Report prepared by the EPO or JPO \$890.00 (970) International preliminary examination fee (37 CFR 1.482) not paid to U.S. PATENT AND TRADEMARK OFFICE but international search fee (37 CFR 1.445(a)(2)) paid to U.S. PATENT AND TRADEMARK OFFICE \$740.00 (958) International preliminary examination fee (37 CFR 1.482) paid to U.S. PATENT AND TRADEMARK OFFICE but all claims did not satisfy provisions of PCT Article 33(1)-(4) \$710.00 (956) International preliminary examination fee (37 CFR 1.482) paid to U.S. PATENT AND TRADEMARK OFFICE and all claims satisfied provisions of PCT Article 33(1)-(4) \$100.00 (962) <div style="text-align: right;">ENTER APPROPRIATE BASIC FEE AMOUNT =</div>	CALCULATIONS	PTO USE ONLY																																																																														
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<table border="1" style="width:100%; border-collapse: collapse;"> <tr> <th style="width:15%;">Claims</th> <th style="width:20%;">Number Filed</th> <th style="width:20%;">Number Extra</th> <th style="width:20%;">Rate</th> <th style="width:15%;"></th> <th style="width:10%;"></th> </tr> <tr> <td>Total Claims</td> <td>20 - 20 =</td> <td>--</td> <td>X\$18.00 (966)</td> <td>\$ --</td> <td></td> </tr> <tr> <td>Independent Claims</td> <td>2 - 3 =</td> <td>--</td> <td>X\$84.00 (964)</td> <td>\$ --</td> <td></td> </tr> <tr> <td colspan="3">Multiple dependent claim(s) (if applicable)</td> <td>+ \$280.00 (968)</td> <td>\$ --</td> <td></td> </tr> <tr> <td colspan="4" style="text-align: right;">TOTAL OF ABOVE CALCULATIONS =</td> <td>\$ 1,040.00</td> <td></td> </tr> <tr> <td colspan="4">Reduction for 1/2 for filing by small entity, if applicable (see below).</td> <td style="text-align: center;">+</td> <td>\$ 520.00</td> </tr> <tr> <td colspan="4" style="text-align: right;">SUBTOTAL =</td> <td>\$ 520.00</td> <td></td> </tr> <tr> <td colspan="4">Processing fee of \$130.00 (156) for furnishing the English translation later than months from the earliest claimed priority date (37 CFR 1.492(f)). 20 <input type="checkbox"/> 30 <input type="checkbox"/></td> <td style="text-align: center;">+</td> <td>\$ --</td> </tr> <tr> <td colspan="4" style="text-align: right;">TOTAL NATIONAL FEE =</td> <td>\$ 520.00</td> <td></td> </tr> <tr> <td colspan="4">Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). \$40.00 (581) per property</td> <td style="text-align: center;">+</td> <td>\$ 40.00</td> </tr> <tr> <td colspan="4" style="text-align: right;">TOTAL FEES ENCLOSED =</td> <td>\$ 560.00</td> <td></td> </tr> <tr> <td colspan="4"></td> <td style="text-align: right;">Amount to be refunded:</td> <td>\$</td> </tr> <tr> <td colspan="4"></td> <td style="text-align: right;">charged:</td> <td>\$</td> </tr> </table>	Claims	Number Filed	Number Extra	Rate			Total Claims	20 - 20 =	--	X\$18.00 (966)	\$ --		Independent Claims	2 - 3 =	--	X\$84.00 (964)	\$ --		Multiple dependent claim(s) (if applicable)			+ \$280.00 (968)	\$ --		TOTAL OF ABOVE CALCULATIONS =				\$ 1,040.00		Reduction for 1/2 for filing by small entity, if applicable (see below).				+	\$ 520.00	SUBTOTAL =				\$ 520.00		Processing fee of \$130.00 (156) for furnishing the English translation later than months from the earliest claimed priority date (37 CFR 1.492(f)). 20 <input type="checkbox"/> 30 <input type="checkbox"/>				+	\$ --	TOTAL NATIONAL FEE =				\$ 520.00		Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). \$40.00 (581) per property				+	\$ 40.00	TOTAL FEES ENCLOSED =				\$ 560.00						Amount to be refunded:	\$					charged:	\$		
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- a. ☒ Small entity status is hereby claimed.
- b. ☒ A check in the amount of \$ 560.00 to cover the above fees is enclosed.
- c. ☐ Please charge my Deposit Account No. 02-4800 in the amount of \$_____ to cover the above fees. A duplicate copy of this sheet is enclosed.
- d. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 02-4800. A duplicate copy of this sheet is enclosed.
- NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.**

SEND ALL CORRESPONDENCE TO:

Benton S. Duffett, Jr.
 BURNS, DOANE, SWECKER & MATHIS, L.L.P.
 P.O. Box 1404
 Alexandria, Virginia 22313-1404
 (703) 836-6620

SIGNATURE

Benton S. Duffett, Jr.

NAME

22,030

REGISTRATION NUMBER

December 14, 2001

DATE

Patent
Attorney's Docket No. 003300-877

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of)
ANDERS HEYDEN) BOX PCT
Application No.: (unassigned)) Attention: DO/EO/US
Filed: December 14, 2001) Group Art Unit: (unassigned)
For: MICRSCOPE FILTER FOR) Examiner: (unassigned)
AUTOMATIC CONTRAST)
ENHANCEMENT)

TRANSMITTAL OF FORMAL DRAWINGS

Assistant Commissioner for Patents
Washington, D.C. 20231

Sir:

Applicant submits herewith three (3) sheets of formal drawings (i.e., Figs. 1 to 4).

The examination and allowance of the Application are respectfully requested.

Respectfully submitted,

BURNS, DOANE, SWECKER & MATHIS, L.L.P.

By: Benton S. Duffett, Jr.

Benton S. Duffett, Jr.
Registration No. 22,030

P.O. Box 1404
Alexandria, Virginia 22313-1404
(703) 836-6620

Filed: December 14, 2001

Patent

Attorney's Docket No. 003300-877**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

In re Patent Application of)	
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ANDERS HEYDEN)	BOX PCT
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Application No.: (unassigned))	Attention: DO/EO/US
)	
Filed: December 14, 2001)	Group Art Unit: (unassigned)
)	
For: MICROSCOPE FILTER FOR)	Examiner: (unassigned)
AUTOMATIC CONTRAST)	
ENHANCEMENT)	

PRELIMINARY AMENDMENT

Assistant Commissioner for Patents
Washington, D.C. 20231

Sir:

This is a national phase filing of International Application No. PCT/SE00/01376,
filed June 29, 2000.

Please amend the above-identified Application as indicated.

IN THE ABSTRACT:

Please add the Abstract of the Disclosure that is provided on a separate sheet.

IN THE SPECIFICATION:

Page 1, before line 1, insert:

--This is a 35 U.S.C. §371 filing of International Application No.

PCT/SE00/01376, filed June 29, 2000 that designates the United States of America, and
claims the benefit of the filing of Swedish Application No. 9902641-1, filed July 9, 1999

under 35 U.S.C. §119(a), and U.S. Provisional Application No. 60/150,440, filed August 24, 1999 under 35 U.S.C. §119(e).--

IN THE CLAIMS:

Kindly replace claims 3 and 5 to 12 as follows:

3. (Amended) A microscope as claimed in claim 1, characterised in that it also comprises a second calculating means (25), which is connected to the image sensor and the first calculating means, and which is adapted

to Fourier transform the recorded image,

to determine a limit frequency below which the major part of the light energy of the transformed image is to be found, and

to provide the first calculating means with the limit frequency as a value of the position of the peak value.

5. (Amended) A microscope as claimed in claim 1, characterised in that the spatial frequency of the sensor elements is at least 1.5 times higher, and preferably at least 2 times higher, than the maximum spatial frequency of the image.

6. (Amended) A microscope as claimed in claim 3 characterised in that the spatial frequency of the sensor elements is at least 1.5 times higher, and preferably at least 2 times higher, than the limit frequency.

7. (Amended) A microscope as claimed in claim 1, characterised in that the filter function (17) is continuous and strictly growing from zero frequency to the position of the peak value and strictly increasing toward zero for increasing frequencies from the position of the peak value.

8. (Amended) A microscope as claimed in claim 1, characterised in that the filter function (17) is a convolution of two one-dimensional filter functions.

9. (Amended) A microscope as claimed in claim 1, characterised in that the filtered image is stored in a storage means (26).

10. (Amended) A microscope as claimed in claim 1, characterised in that it also comprises a display (8) on which the filtered image is shown.

11. (Amended) A microscope as claimed in claim 1, characterised in that the first calculating means is adapted
to divide the recorded image into colour components, and
to provide a digital filter for each of the colour components.

12. (Amended) A microscope as claimed in claim 1, characterised in that the first value essentially is one.

Kindly add the following new Claims 13 to 20:

13. (New) A microscope as claimed in claim 2, characterised in that it also comprises a second calculating means (25), which is connected to the image sensor and the first calculating means, and which is adapted

to Fourier transform the recorded image,

to determine a limit frequency below which the major part of the light energy of the transformed image is to be found, and

to provide the first calculating means with the limit frequency as a value of the position of the peak value.

14. (New) A microscope as claimed in claim 2, characterised in that the spatial frequency of the sensor elements is at least 1.5 times higher, and preferably at least 2 times higher, than the maximum spatial frequency of the image.

15. (New) A microscope as claimed in claim 3, characterised in that the spatial frequency of the sensor elements is at least 1.5 times higher, and preferably at least 2 times higher, than the maximum spatial frequency of the image.

16. (New) A microscope as claimed in claim 13, characterised in that the spatial frequency of the sensor elements is at least 1.5 times higher, and preferably at least 2 times higher, than the maximum spatial frequency of the image.

17. (New) A microscope as claimed in claim 4 characterised in that the spatial frequency of the sensor elements is at least 1.5 times higher, and preferably at least 2 times higher, than the limit frequency.

18. (New) A microscope as claimed in claim 2, characterised in that the filter function (17) is continuous and strictly growing from zero frequency to the position of the peak value and strictly increasing toward zero for increasing frequencies from the position of the peak value.

19. (New) A microscope as claimed in claim 2, characterised in that the filter function (17) is a convolution of two one-dimensional filter functions.

20. (New) A microscope as claimed in claim 2, characterised in that the filtered image is stored in a storage means (26).

REMARKS


The present amendment adds an Abstract of the Disclosure on a separate sheet and modifies the claim format so as to eliminate the use of multiple dependency.

An Information Disclosure Statement and Transmittal of Formal Drawings are being filed concurrently herewith.

The examination and allowance of the Application are respectfully requested.

Respectfully submitted,

BURNS, DOANE, SWECKER & MATHIS, L.L.P.

By: 

Benton S. Duffett, Jr.
Registration No. 22,030

P.O. Box 1404
Alexandria, Virginia 22313-1404
(703) 836-6620

Filed: December 14, 2001

Application No. (unassigned)
Attorney's Docket No. 003300-877
Page 1

Attachment to Preliminary Amendment dated December 14, 2001

Abstract of the Disclosure

A microscope comprises an object holder (3), optics which in an image plane form an image of an object (2) which is placed in the object holder, a digital image sensor (56) which has a number of sensor elements (6) for recording the image. The image sensor and the image plane are arranged in such a manner that the spatial frequency of the sensor elements (6) is higher than the maximum spatial frequency of the image. The microscope further comprises at least a first calculating means (24) which is connected to the image sensor (5) and which is adapted to provide a two-dimensional filter function, which essentially has the value one at the spatial frequency zero, a value higher than zero at a spatial frequency above the maximum spatial frequency of the image and a peak value between said frequencies, to calculate a digital filter corresponding to a two-dimensional inverse Fourier transform of the filter function, and to filter a recorded image by means of the digital filter.

Attachment to Preliminary Amendment dated December 14, 2001

Marked-up Claims 3 and 5 to 12

3. (Amended) A microscope as claimed in claim 1 [or 2], characterised in that it also comprises a second calculating means (25), which is connected to the image sensor and the first calculating means, and which is adapted

to Fourier transform the recorded image,

to determine a limit frequency below which the major part of the light energy of the transformed image is to be found, and

to provide the first calculating means with the limit frequency as a value of the position of the peak value.

5. (Amended) A microscope as claimed in claim 1, [2 or 3,] characterised in that the spatial frequency of the sensor elements is at least 1.5 times higher, and preferably at least 2 times higher, than the maximum spatial frequency of the image.

6. (Amended) A microscope as claimed in claim 3 [or 4] characterised in that the spatial frequency of the sensor elements is at least 1.5 times higher, and preferably at least 2 times higher, than the limit frequency.

7. (Amended) A microscope as claimed in [any one of the preceding claims] claim 1, characterised in that the filter function (17) is continuous and strictly growing

Attachment to Preliminary Amendment dated December 14, 2001

Marked-up Claims 3 and 5 to 12

from zero frequency to the position of the peak value and strictly increasing toward zero for increasing frequencies from the position of the peak value.

8. (Amended) A microscope as claimed in [any one of the preceding claims] claim 1, characterised in that the filter function (17) is a convolution of two one-dimensional filter functions.

9. (Amended) A microscope as claimed in [any one of the preceding claims] claim 1, characterised in that the filtered image is stored in a storage means (26).

10. (Amended) A microscope as claimed in [any one of the preceding claims] claim 1, characterised in that it also comprises a display (8) on which the filtered image is shown.

11. (Amended) A microscope as claimed in [any one of the preceding claims] claim 1, characterised in that the first calculating means is adapted to divide the recorded image into colour components, and to provide a digital filter for each of the colour components.

Attachment to Preliminary Amendment dated December 14, 2001

Marked-up Claims 3 and 5 to 12

12. (Amended) A microscope as claimed in [any one of the preceding claims]
claim 1, characterised in that the first value essentially is one.

3/ppts

MICROSCOPE FILTER FOR AUTOMATIC CONTRAST ENHANCEMENTField of the Invention

The present invention relates to a microscope having an image processing system and a method for such a microscope.

Background of the Invention

Microscopes are frequently provided with a camera for recording digital images. The digital image can then be processed in a number of different ways. For example, biological preparations are studied under a microscope, provided with an image processing system. The image processing system can then be used to recognise a certain type of organisms or cells to be able to automatically determine the presence of the organism or cell in the specimen.

However, it is sometimes difficult to obtain a sufficiently sharp image to be able to easily carry out automatic recognition and determination of a special type of organisms. This relates especially to small organisms or cells.

For easier automatic recognition, it is possible to use digital filters to improve the contrast in the image and, thus, make it easier for the image processing system to automatically recognise the cells or organisms.

A standard method of improving the contrast in an image is what is referred to as the High-Boost method, in which the image is multiplied by a factor, whereupon a low-pass filtered image is subtracted from the result of the multiplication.

US Patent 5,696,850 discloses a method and a system using an algorithm for increasing the sharpness of reproduced images, the system having a digital camera and a reproduction device. According to the method, the transfer functions of the camera and the reproduction device are determined by measuring them accurately. However, the

measuring operation requires advanced and expensive apparatus and is carried out in one direction at a time since it is difficult to make a two-dimensional measurement of the transfer function. Besides, the measurement of the optical transfer function must be effected each time something has been changed in the optical system. Then the inverse Fourier transform of the two combined transfer functions is used to calculate a one-dimensional filter. The filter is used to filter a recorded image by first applying the filter in one direction and subsequently in a direction at right angles to the first.

However, satisfactory results are not achieved by the prior art techniques. Nor is it possible to measure the transfer function for a microscope in the same accurate way as for a camera.

A further problem of the method and the device according to the US patent is that the noise at high frequencies will be amplified in an uncontrolled manner if the value of the transfer function is small for high frequencies. Moreover, a satisfactory result is not achieved with two one-dimensional filters applied successively.

There is thus a need for a method and a microscope with an image processing system which increase the sharpness of an image while at the same time the noise is restricted.

Summary of the Invention

An object of the present invention is to provide a microscope, which increases the sharpness while at the same time the noise is restricted in an image taken by means of the microscope.

A further object of the present invention is to provide a method for recording and processing of digital images so as to obtain sharp images.

These objects are achieved by a microscope and a method for the same according to the appended claims.

A microscope with an image processing system according to the invention comprises an object holder, optics

which in an image plane form an image of an object placed in the image holder, and a digital image sensor, which has a number of sensor elements, for recording the image. A microscope according to the invention is characterised in that the image sensor and the image plane are arranged in such manner that the spatial frequency of the sensor elements is higher than the maximum spatial frequency of the image. The microscope further comprises at least one calculating means connected to the sensor, a first calculating means being adapted to provide a two-dimensional filter function, which essentially has a first value at the spatial frequency zero, a value greater than zero at a spatial frequency above the maximum spatial frequency of the image and a peak value between the spatial frequency zero and the spatial frequency of the second value, to calculate a digital filter corresponding to a two-dimensional inverse transform of the filter function, and to filter a recorded image by means of the digital filter.

The filter function decreases toward zero for spatial frequencies above the spatial frequency of the peak value.

The first value is preferably one since no attenuation usually occurs at the spatial frequency zero. It is, however, possible to have amplification also at the spatial frequency zero in the image.

The spatial frequency of the sensor elements is defined as the inverse of the double distance between two adjoining sensor elements.

Preferably, the microscope is adapted to calculate a digital filter when a user initiates such calculation. Alternatively, the microscope is adapted to calculate a digital filter each time a new image is recorded by means of the image sensor, which, however, does not yield any particular advantages.

By using a two-dimensional filter, it is possible to obtain a rotationally symmetrical result. By the spatial

frequency of the sensor elements being higher than the maximum spatial frequency of the image, it is possible to use a digital filter, which corresponds to a filter function which has a value different from zero at frequencies above the maximum spatial frequency of the image. The use of such a filter results in noise reduction in the image.

According to an alternative embodiment, the filter function is a convolution of two one-dimensional filter functions. The digital filter, however, will then not be rotationally symmetrical.

The image sensor is advantageously a semiconductor sensor in the form of, for instance, a CMOS sensor or a CCD (charge coupled device) which is composed of a number of sensor elements equidistantly spaced from each other. The spatial frequency of the sensor elements is the inverse of the double distance between two adjoining sensor elements.

However, the image sensor can be some other kind of image sensor such as a vidicon. What is essential for the invention is that the image sensor has a better resolution than the maximum spatial frequency of the image.

Preferably, the sensor elements have a spatial frequency which is at least 1.5 times, advantageously at least 2 times higher, than the maximum spatial frequency of the image.

According to a preferred embodiment of the present invention, the microscope also comprises an input means for inputting values providing information about the filter function.

Preferably, the microscope is adapted to make an estimate of the limit frequency of the optics by recording an image by means of the image sensor. The recorded image is Fourier-transformed so that an image in the frequency plane is obtained. The first calculating means calculates on the basis of the Fourier-transformed image a limit frequency. The integrated signal up to the limit frequency is the major part of the total light energy of the

image and advantageously at least 90%, preferably at least 95%, of the total light energy in the transformed image. The limit frequency measured in the manner described is not the same as the maximum frequency which the optical system lets through, but is a usable estimate thereof.

The limit frequency is used to calculate the position of the peak value of the filter function. It is advantageous to let the position of the peak value depend also on the values of the appearance of the filter function, which are inputted with the aid of the input means.

If the microscope is adapted to estimate the limit frequency, the estimate is preferably made when a user initiates such an estimate, but alternatively the estimate is made each time a new image is recorded.

The filter function is advantageously strictly increasing up to the limit frequency and subsequently strictly decreasing so that the filter function up to the limit frequency conforms as far as possible with the inverse of an actual transfer function. As a rule, an actual transfer function is strictly decreasing up to the maximum frequency which the optical system lets through.

It is possible within the scope of the invention to have a filter function which is neither strictly increasing up to the limit frequency nor strictly decreasing after the limit frequency.

It is advantageous to let the filter function be continuously derivable since this allows a digital filter having a smaller spatial extent and, thus, a more rapid filtration.

It goes without saying that the above features can be combined in the same embodiment.

In order to further illustrate the invention, detailed embodiments thereof will now be described, without the invention being considered to be restricted thereto.

Brief Description of the Drawings

Fig. 1 is a schematic view of a microscope according to an embodiment of the present invention.

Fig. 2 is a block diagram of the function of a microscope according to the invention.

Fig. 3 illustrates the filter function as a function of the frequency in a microscope according to the present invention.

Fig. 4 shows a digital filter according to the present invention.

Detailed Description of the Invention

Fig. 1 is a schematic view of a microscope according to the present invention. The microscope has a source of light 1, which illuminates an object 2 placed on an object holder 3. Light from the object is collected with a microscope objective 4. A digital image sensor is arranged at a distance from the microscope objective 4. According to this preferred embodiment, the digital image sensor is a CCD. The CCD 5, the microscope objective 4 and the object 2 are arranged in a spaced-apart relationship so that the image plane of the microscope objective coincides with the surface of the image sensor 5. The CCD is formed with a large number of sensor elements 6 which are mutually spaced apart a distance d . Each picture element corresponds to a pixel in a digital image. The image sensor 5 is connected to an image processing means 7, which in turn is connected to a display 8 and an input means in the form of a keyboard 9. In the image processing means, a first calculating means 24 and a second calculating means 25 are arranged. Between the microscope objective 4 and the CCD 5, lenses 10 are arranged to transfer the image to the CCD 5. The optical system consisting of the microscope objective 4 and the lenses 10 has a combined transfer function which describes how different spatial frequencies of the object 2 are transferred to the image plane. Depending on the design of the objective 4 and the lenses 10, spatial frequencies of

different degrees are transferred from the object 2. The maximum spatial frequency that is transferred from the object 2 to the CCD 5 is usually defined as the resolution of the optical system. Thus only structures corresponding to a certain minimum size of the object will be distinguished in the image. The size of the image, however, may vary by varying the mutual arrangement of the CCD 5, the microscope objective 4 and the object 2. The spatial frequency of the sensor elements is defined as the inverse of their double mutual distance $2d$. According to the invention, the object 2, the microscope objective 4, the lenses 10 and the CCD 5 are arranged so that the spatial frequency of the sensor elements is higher than the maximum spatial frequency of the image. The spatial frequency of the sensor elements is preferably 1.5 times higher than the maximum spatial frequency of the image and advantageously at least 2 times higher than the maximum spatial frequency of the image in order to obtain a reduction of noise.

When an object 2 is placed on the object holder 3, an image will be recorded by the image sensor 5. The recorded image is transferred to the image processing means 7, which processes the image before it is shown on the display 8. The image processing in the image processing means 7 is affected by parameters which are inputted via the keyboard 9.

Fig. 2 is a block diagram of the function of the image processing means 7. The recorded image from the CCD 5 is inputted at the top of the figure to block 12 and at the bottom of the figure to block 13. In block 13, a division into the colour components of the image is made, whereupon the divided image is transferred to block 14 for filtration by means of a digital filter. In block 12, a limit frequency (ω_0) is determined by the recorded image being transformed, whereupon ω_0 is calculated as the frequency below which 95% of the integrated signal in the transformed image is present. The calculation of ω_0

can be carried out each time a new picture is taken or when a user of the microscope initiates a determination of ω_0 .

According to the preferred embodiment, a digital filter is calculated when a user initiates such a calculation via the keyboard 9.

Fig. 3 shows a filter function as a function of the frequency which describes an amplification as a function of the frequency.

In block 15, parameters for the transfer function of the filter are fetched from the keyboard or from a memory 23 in the image processing means. Examples of the parameters that can be fetched from the keyboard 9 in block 15 are the amplification of the filter at the limit frequency, the position of the limit frequency and the appearance of the filter function above and below the limit frequency. In block 16, the transfer function 17 of the filter is determined on the basis of the parameters that are fetched into block 15. The filter function 17 is determined as follows:

$$H_f(\omega) = \begin{cases} e^{(\omega/\omega_0)^2 \alpha}, & \omega \leq \omega_0, \\ e^{\alpha \left(\frac{\omega_1^2 + \omega_0^2}{\omega_1^2 + \omega^2} \right) \gamma}, & \omega \geq \omega_0, \end{cases}$$

wherein α , γ and ω_1 are parameters which the user can modify in the input means 9. The parameter ω_0 can either be defined by the user or be determined automatically by the system and indicates the limit frequency. The amplification at the limit frequency is determined by α . γ and ω_1 determine how rapidly the filter fades away at high frequencies.

Thus, the filter function is two-dimensional and dependent on the sum of the frequency ω but independent of an angular parameter, a circular symmetrical function being obtained.

The filter function, however, may have a different appearance and can, for instance, be described by one

polynomial up to the limit value and another polynomial above the limit value. The filter function 17 has essentially the value 1 for the frequency zero and a peak value at the limit frequency (ω_0). After the limit frequency ω_0 , the function decreases. The filter function has, however, a value different from zero above a frequency exceeding the maximum spatial frequency of the image. The limit frequency essentially conforms to the maximum spatial frequency of the image. Once more with reference to Fig. 2, there is made in block 18 a two-dimensional inverse transform of the filter function which was calculated in block 16. The inverse-transformed filter function is digitised and cut off to a suitable size to constitute a digital filter for the recorded image. In block 14, the image of which the colours have been divided is filtered two-dimensionally by means of the digital filter. Subsequently, a voluntary grey-level transformation is made in block 19, whereupon the colours in the image are again put together in block 20. The grey-level transformation is carried out if there is a risk that the grey levels have reached outside permissible values in the filtration. After the processing of the image, the image is shown on the display 8 or stored in a storage means 26.

Fig. 4 illustrates an example of a digital filter 22 which is used in block 14. As is evident from Fig. 4, the filter is circular symmetrical around the top 21. When the image is filtered in block 14, the value in a pixel is multiplied by a value corresponding to the filter at the top 21 and added to the result of the multiplications between the adjoining pixels and a corresponding value in the filter.

A person skilled in the art realises that the invention is not limited to the embodiment shown and that many modifications are feasible within the scope of the invention. For example, block 12 in Fig. 2 can be omitted and the filter function be determined entirely by means of

parameters that are inputted via the keyboard 9 in Fig. 1. A person skilled in the art also realises that blocks 13 and 20 can be omitted if the image is not a colour image.

CLAIMS

1. A microscope comprising
an object holder (3),
optics which in an image plane form an image of an
object (2) which is placed in the object holder, and
5 a digital image sensor (5), which has a number of
sensor elements (6) for recording the image, c h a r -
a c t e r i s e d in that the image sensor and the image
plane are arranged in such manner that the spatial fre-
quency of the sensor elements (6) is higher than the
10 maximum spatial frequency of the image, the microscope
further comprising at least a first calculating means
(24) which is connected to the image sensor (5) and which
is adapted

to provide a two-dimensional filter function, which
15 essentially has a first value at the spatial frequency
zero, a second value which is different from zero at a
spatial frequency above the maximum spatial frequency of
the image and a peak value between the spatial frequency
zero and the spatial frequency of the second value,

20 to calculate a digital filter which corresponds to a
two-dimensional inverse Fourier transform of the filter
function, and

to filter a recorded image by means of the digital
filter.

25 2. A microscope as claimed in claim 1, c h a r -
a c t e r i s e d in that it also comprises an input
means (9) connected to the calculating means for input-
ting values which provide information about at least one
of the peak value of the filter function, the spatial
30 frequency of the peak value, the filter function for spa-
tial frequencies below the spatial frequency of the peak
value, or the filter function for spatial frequencies
above the spatial frequency of the peak value, the input-
ting means being connected to the calculating means and

the inputted values being used by the calculating means to provide the filter function.

3. A microscope as claimed in claim 1 or 2, characterised in that it also comprises a second calculating means (25), which is connected to the image sensor and the first calculating means, and which is adapted

to Fourier transform the recorded image, to determine a limit frequency below which the major part of the light energy of the transformed image is to be found, and

to provide the first calculating means with the limit frequency as a value of the position of the peak value.

4. A microscope as claimed in claim 3, characterised in that the limit frequency is determined as the frequency below which at least 90% of the energy in the image is to be found.

5. A microscope as claimed in claim 1, 2 or 3, characterised in that the spatial frequency of the sensor elements is at least 1.5 times higher, and preferably at least 2 times higher, than the maximum spatial frequency of the image.

6. A microscope as claimed in claim 3 or 4, characterised in that the spatial frequency of the sensor elements is at least 1.5 times higher, and preferably at least 2 times higher, than the limit frequency.

7. A microscope as claimed in any one of the preceding claims, characterised in that the filter function (17) is continuous and strictly growing from zero frequency to the position of the peak value and strictly increasing toward zero for increasing frequencies from the position of the peak value.

8. A microscope as claimed in any one of the preceding claims, characterised in that the filter

function is a convolution of two one-dimensional filter functions.

9. A microscope as claimed in any one of the preceding claims, characterised in that the filtered image is stored in a storage means (26).

10. A microscope as claimed in any one of the preceding claims, characterised in that it also comprises a display (8) on which the filtered image is shown.

11. A microscope as claimed in any one of the preceding claims, characterised in that the first calculating means is adapted to divide the recorded image into colour components, and

to provide a digital filter for each of the colour components.

12. A microscope as claimed in any one of the preceding claims, characterised in that the first value essentially is one.

13. A method for a microscope, characterised by the steps of

arranging an image sensor (5) which has a plurality of sensor elements (6), optics (4, 10) and an object (2) at a mutual distance from each other, so that an image of the object is formed on the image sensor (5), the spatial frequency of the sensor elements (6) being higher than the maximum spatial frequency of the image,

recording the image by means of the image sensor (5),

providing a two-dimensional filter function, which essentially has a first value at the spatial frequency zero, a second value different from zero at a spatial frequency which is higher than the maximum spatial frequency of the image and a peak value between the spatial frequency zero and the spatial frequency of the second value,

calculating a digital filter which corresponds to a two-dimensional inverse Fourier transform of the filter function, and

5 filtering the recorded image by means of the digital filter.

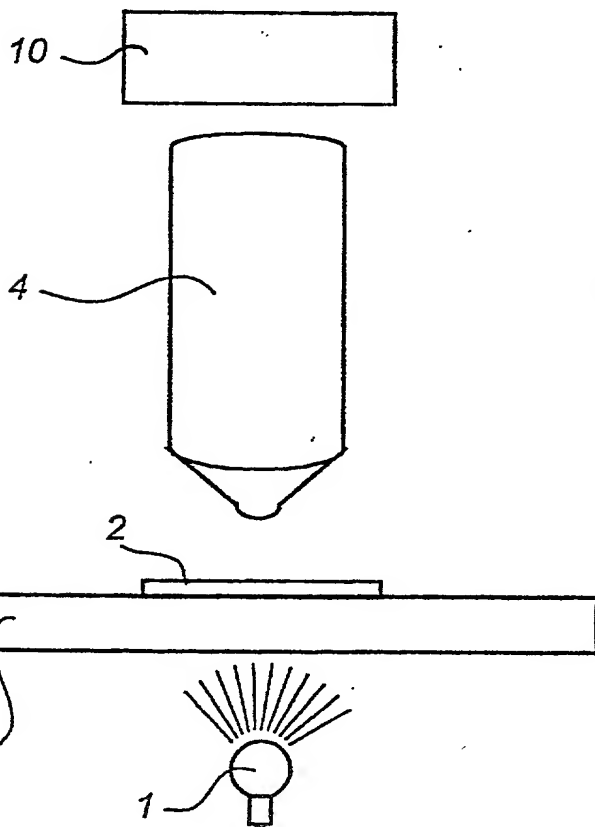
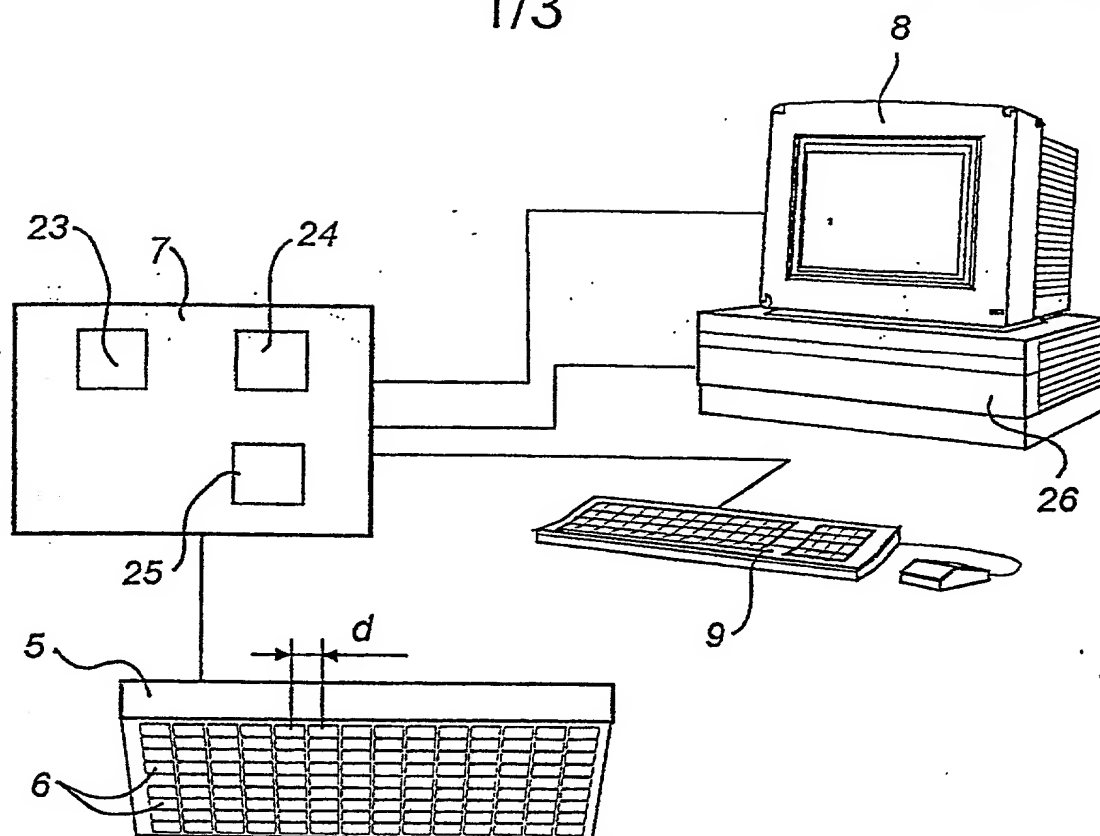


Fig. 1

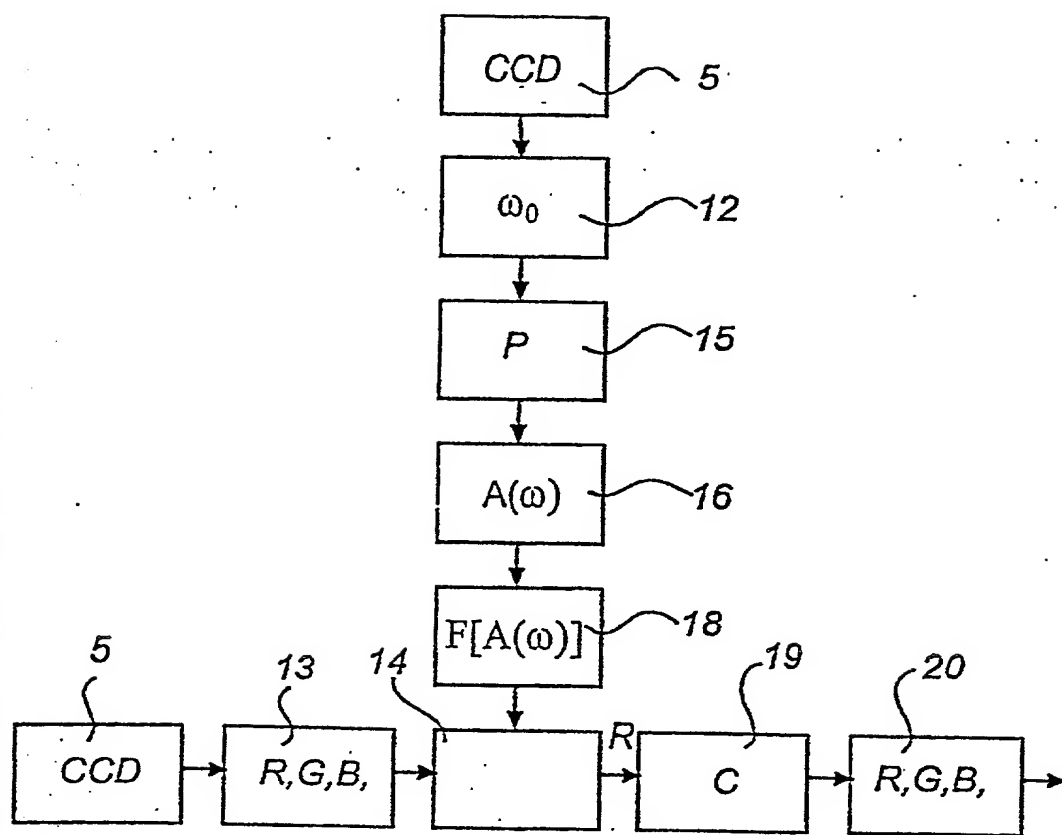


Fig. 2

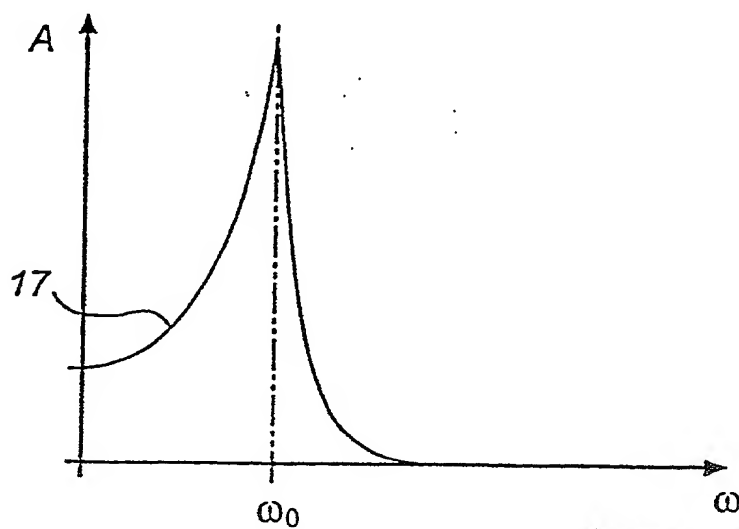


Fig. 3

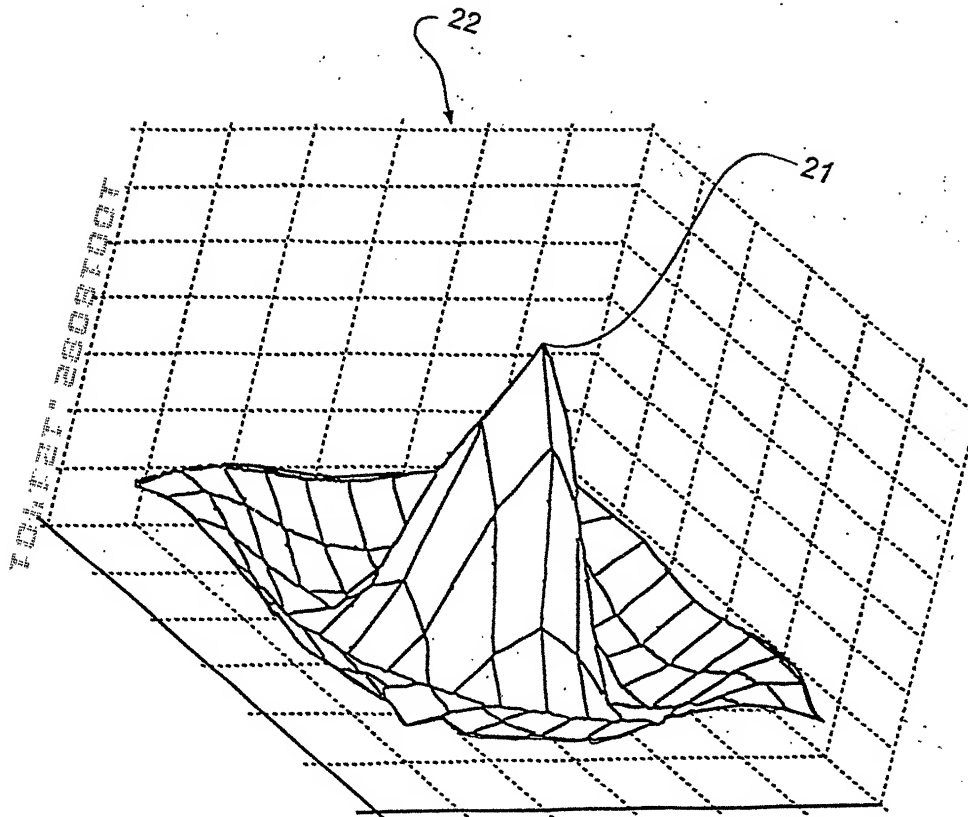


Fig. 4

COMBINED DECLARATION FOR PATENT APPLICATION AND POWER OF ATTORNEY
(Includes Reference to Provisional and PCT International Applications)

Attorney's Docket No.

003300-877

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name;

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

Microscope filter for automatic contrast enhancement

the specification of which (check only one item below):

☒ is attached hereto.

☐ was filed as United States application

Number _____

on _____

and was amended

on _____ (if applicable).

☒ was filed as PCT international application

Number PCT/SE00/01376

on 29 June 2000

and was amended

on _____ (if applicable).

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose to the Office all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, §1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, §119 (a)-(e) of any foreign application(s) for patent or inventor's certificate or of any PCT international application(s) designating at least one country other than the United States of America listed below and have also identified below any foreign application(s) for patent or inventor's certificate or any PCT international application(s) designating at least one country other than the United States of America filed by me on the same subject matter having a filing date before that of the application(s) of which priority is claimed:

PRIOR FOREIGN/PCT APPLICATION(S) AND ANY PRIORITY CLAIMS UNDER 35 U.S.C. §119:

COUNTRY (if PCT, indicate "PCT")	APPLICATION NUMBER	DATE OF FILING (day, month, year)	PRIORITY CLAIMED UNDER 35 U.S.C. §119
Sweden	9902641-1	9 July 1999	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No
			<input type="checkbox"/> Yes <input type="checkbox"/> No
			<input type="checkbox"/> Yes <input type="checkbox"/> No
			<input type="checkbox"/> Yes <input type="checkbox"/> No

I hereby claim the benefit under Title 35, United States Code § 119(e) of any United States provisional application(s) listed below.

60/150 440

(Application Number)

24 August 1999

(Filing Date)

(Application Number)

(Filing Date)

COMBINED DECLARATION FOR PATENT APPLICATION AND POWER OF ATTORNEY (CONTINUED)
(Includes Reference to Provisional and PCT International Applications)

Attorney's Docket No.
003300-877

I hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) or PCT international application(s) designating the United States of America that is/are listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in that/those prior application(s) in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose to the Office all information known to me to be material to the patentability as defined in Title 37, Code of Federal Regulations §1.56, which became available between the filing date of the prior application(s) and the national or PCT international filing date of this application:

PRIOR U.S. APPLICATIONS OR PCT INTERNATIONAL APPLICATIONS DESIGNATING THE U.S. FOR BENEFIT UNDER 35 U.S.C. 120:

U.S. APPLICATIONS

STATUS (check one)

U.S. APPLICATION NUMBER

U.S. FILING DATE

PATENTED

PENDING

ABANDONED

PCT APPLICATIONS DESIGNATING THE U.S.

PCT APPLICATION NO.

PCT FILING DATE

U.S. APPLICATION NUMBERS
ASSIGNED (if any)

I hereby appoint the following attorneys and agent(s) to prosecute said application and to transact all business in the Patent and Trademark Office connected therewith and to file, prosecute and to transact all business in connection with international applications directed to said invention:

30
William L. Mathis
Robert S. Swecker
Platon N. Mandros
Benton S. Duffett, Jr.
Norman H. Stepno
Ronald L. Grudziecki
Frederick G. Michaud, Jr.
Alan E. Kopecki
Regis E. Slutter
Samuel C. Miller, III
Robert G. Mukai
George A. Hovanec, Jr.
James A. LaBarre
E. Joseph Gess

17,337
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22,124
22,030
22,716
24,970
26,003
25,813
26,999
27,360
28,531
28,223
28,632
28,510

R. Danny Huntington
Eric H. Weisblatt
James W. Peterson
Teresa Stanek Rea
Robert E. Krebs
William C. Rowland
T. Gene Dillahunty
Patrick C. Keane
Bruce J. Boggs, Jr.
William H. Benz
Peter K. Skiff
Richard J. McGrath
Matthew L. Schneider
Michael G. Savage

27,903
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30,888
25,423
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31,917
29,195
32,814
32,596

Gerald F. Swiss
Michael J. Ure
Charles F. Wieland III
Bruce T. Wieder
Todd R. Walters
Ronni S. Jillions
Harold R. Brown III
Allen R. Baum
Steven M. du Bois
Brian P. O'Shaughnessy

30,113
33,089
33,096
33,815
34,040
31,979
36,341
36,086
35,023
32,747



21839

and: None

Address all correspondence to:



21839

Steven M. du Bois
BURNS, DOANE, SWECKER & MATHIS, L.L.P.
P.O. Box 1404
Alexandria, Virginia 22313-1404

Address all telephone calls to: Steven M. du Bois at (703) 836-6620.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

COMBINED DECLARATION FOR PATENT APPLICATION AND POWER OF ATTORNEY (CONTINUED)
(Includes Reference to Provisional and PCT International Applications)

ATTORNEY'S DOCKET NO.
003300-877

FULL NAME OF SOLE OR FIRST INVENTOR

Anders Heyden

SIGNATURE

Anders Heyden

DATE

7/11-01

RESIDENCE

Dalby, Sweden *SE*

CITIZENSHIP

Sweden

POST OFFICE ADDRESS

Skogslyckevägen 9, 240 10 Dalby, Sweden

FULL NAME OF SECOND JOINT INVENTOR, IF ANY

SIGNATURE

DATE

RESIDENCE

CITIZENSHIP

POST OFFICE ADDRESS

FULL NAME OF THIRD JOINT INVENTOR, IF ANY

SIGNATURE

DATE

RESIDENCE

CITIZENSHIP

POST OFFICE ADDRESS

FULL NAME OF FOURTH JOINT INVENTOR, IF ANY

SIGNATURE

DATE

RESIDENCE

CITIZENSHIP

POST OFFICE ADDRESS

FULL NAME OF FIFTH JOINT INVENTOR, IF ANY

SIGNATURE

DATE

RESIDENCE

CITIZENSHIP

POST OFFICE ADDRESS

FULL NAME OF SIXTH JOINT INVENTOR, IF ANY

SIGNATURE

DATE

RESIDENCE

CITIZENSHIP

POST OFFICE ADDRESS

FULL NAME OF SEVENTH JOINT INVENTOR, IF ANY

SIGNATURE

DATE

RESIDENCE

CITIZENSHIP

POST OFFICE ADDRESS

FULL NAME OF EIGHTH JOINT INVENTOR, IF ANY

SIGNATURE

DATE

RESIDENCE

CITIZENSHIP

POST OFFICE ADDRESS

FULL NAME OF NINTH JOINT INVENTOR, IF ANY

SIGNATURE

DATE

RESIDENCE

CITIZENSHIP

POST OFFICE ADDRESS